

R&D NETWORK - CASE STUDY AND SOCIAL NETWORK ANALYSIS

Completed Research Paper

Marissa Takahashi

The University of Queensland Business School
St Lucia, Brisbane, Australia
m.takahashi@business.uq.edu.au

Abstract

This study examines the network of R&D project teams within a global software company. These R&D teams conduct research projects that aim to advance the state-of-the-art of the knowledge in their respective domains. In addition, these teams have the mandate to commercially exploit their results. To achieve these tasks, R&D teams collaborate with a complex network of stakeholders within their global ecosystem dispersed geographically and across time zones.

This study aims to investigate how network characteristics vary across the different R&D teams and how these network characteristics could influence the performance of these teams. We present the results of the exploratory case study conducted during the first phase of the study when there was a dearth in the understanding of the phenomenon of how research impact, a measure of research performance, is created. The results of the subsequent multiple case studies and network analysis are also presented.

Keywords: *knowledge networks, knowledge sharing, social networks, collaboration, R&D*

Introduction

Intensifying competition and globalization motivate companies to invest substantially in R&D to create innovations that fuel their growth and sustain their competitive advantage (Ojanen and Vuola, 2006; Balachandra and Friar, 1997). For instance, Microsoft spent U\$9.4B on R&D in 2011 while Intel spent U\$8.4B (Krantz, 2012). Corporate research departments have the mandate to fill their company's innovation pipeline with research outcomes that provide incremental innovations for existing products and services or create breakthrough innovations that allows the development of disruptive technologies or business models.

In order to fulfill the abovementioned innovation mandate, corporate researchers engage in open innovation strategies by co-innovating with external parties such academia, partners, and customers. Global companies with research departments tend to create global corporate research in order to tap into the local innovations and expertise that are available in diverse areas around the world. In addition to interacting with external partners, corporate researchers must also navigate through the maze of internal stakeholders to find and secure the much-needed buy-in for their research outcomes, i.e., to achieve research impact. Whereas in academic institutions, research impact is primarily achieved through research publications and citations, in corporate research environment, research impact is achieved when product groups take-up the research outcomes in the form of prototypes or leading edge ideas and further develop these research artifacts into commercial products or services.

The aim of this study is to understand in the context of corporate research, *“Why some research projects are able to create research impact while other projects struggle?”* in general, and in particular, *“Does the network characteristics of projects and their project stakeholders play a role in creating research impact?”* As a prelude to answering these questions, an exploratory study was conducted at SCorp Research (a pseudo name), the corporate research division of a global software company. This study is motivated by a practical concern that SCorp Research is facing with respect to impact generation of its research projects, in particular, publicly-funded projects (PFPs). These PFPs are funded jointly by government funding agency and SCorp and are conducted jointly by university partners and SCorp.

This research makes a number of contributions to knowledge. First, understanding how knowledge workers collaborate within R&D networks to achieve research impact is a first step towards designing information systems that can facilitate this collaboration. R&D network is the epitome of collaboration among knowledge workers. Davenport (2005) classifies knowledge work into four types: transaction (routine work); integration (systematic, repeatable work); expert (judgment-oriented work); and collaboration (improvisational work). Whereas technological advances have provided ICT tools and knowledge management systems (KMS) to support the first three types of knowledge work (e.g., process flow diagrams for transaction work; interactive process support for integration work; and expert systems for judgment work), there is a dearth of tools designed to support collaboration work such as those performed by researchers. A survey of R&D workers found that researchers use relatively old-fashioned collaboration tools – 65% use telephone and video conferences and 62% travel for face-to-face meetings. Other researchers use central knowledge databases and global communities of practice but these are confined to respondents at companies considered as high-performing innovators (McKinsey 2011). It is ironic that these teams work on sophisticated systems to create artifacts that are at the cutting-edge of technology and yet their collaborations still relies on older technologies such as telephone and email. The insights gained can provide useful input in the design of effective collaboration-centric KMS or newer social networking systems, thereby opening up a new avenue of research.

Second, identification of network characteristics that facilitate research performance is first step toward developing strategies for best practices in knowledge-intensive R&D network. Insights gained can provide guidance to corporate managers as well as decision-makers at funding institutions heavily investing in R&D consortia in their quest to optimize the impact of these funded projects. While there are studies on research performance of academic R&D networks as well as corporate R&D networks (e.g., Reagans & McEvily 2003, Hansen 2002, Allen 2007). There is a dearth of studies on joint consortia and even less studies that look at research impact process from the corporate perspective. This is of strategic importance because the increasing complexity of research problems requires concerted effort from both public and private organizations.

Related Literature

R&D Networks and Knowledge Transfer

A common theme emerging in studies of project teams within organizations is that the traditional corporate structures are generally inefficient in facilitating the transfer of knowledge within those structures (Allen et al. 2007). Informal networks within those formal structures tend to be more efficient in transferring and sharing knowledge. Krackhardt and Hanson (1993, p.104) provides an apt metaphor by stating “If the formal organization is the skeleton of a company, the informal is the central nervous systems driving the collective thought processes, actions, and reactions of its business units.” Implicit in many studies of knowledge transfer is the assumption that information or knowledge exchange among actors in the network will affect the relative productivity of the group or the individual (Aral et al. 2006; Cross et al, 2003). It is therefore important to understand how team members in R&D teams communicate, interact, and exchange knowledge in order to enhance their chances of creating excellent research outcomes and achieving research impact.

Furthermore, the increasing trend towards a network form of organization makes it imperative to understand knowledge transfer in networks (Notebloom 2000; Hansen, 2005; Tsai, 2002; Uzzi 1997). Researchers have started to address this issue resulting in resurgence in network research in recent years (Borgatti & Cross 2003). To understand knowledge transfer within networked organization, it is important to understand the complex social context in which the transfer occurs. The network perspective addresses this issue by taking into account not only the focal actors but also how these actors interact with the other actors embedded in the network (Wasserman and Faust 1994). This study views SCorp’s R&D network as a social network. Social networks focus mainly on the social relationships and interactions among human actors. Studies found that networked organizations have advantages over markets because they can mobilize not only the traditional financial and human capital controlled by the firm but also social capital, i.e., the resources embedded in the social relationships among network actors (Burt 2005; Nahapiet and Ghoshal 1998). Social relationships, represented as network structures, are the key to understanding cooperation in knowledge creation and knowledge transfer (Nahapiet & Ghoshal, 1998; von Krogh, 1998).

The network approach has three important benefits. First, the inclusion of the relational and contextual environment of the phenomenon allows the examination of the actors’ connections to other actors within and across the network boundaries to determine the antecedents or consequences of those connections (Borgatti & Foster 2003). Second, cross-level analysis facilitates the examination of the interdependence of actors not only within and across network boundaries but also at different levels within the network (Hitt et al. 2007; Oh et al. 2006). This type of analysis can explain how the micro-level interactions and processes (i.e., knowledge exchange between actors) may influence the emerging macro-level relationships and performance. Third, social network analysis (SNA), which comprises a mix of software algorithms and data collection guidelines, can facilitate quantitative analysis of networks (Wasserman & Faust 1994).

Knowledge Transfer, Network Boundaries, and Research Impact

An important dimension of research performance is research impact. In corporate context, research impact is defined as the contribution of the research project outcome to the existing and future product portfolio; either as enhancement to existing products or a totally new product in itself that can be integrated into the future product portfolio. As previously mentioned, global companies adhere to the principles of open innovation to take advantage of the diversity of knowledge across their vast global ecosystems. As a consequence, their corporate research are typically designed with global reach, i.e., with different research centers/labs spread across the different countries around the world and across different time zones. Further, these research centers are embedded in network of collaborative relationships with the different entities in their global ecosystems. Research impact can potentially be created within this complex network. Interactions among these stakeholders enhance opportunities for research impact and possible innovations through exchange of different resources, including knowledge. Knowledge transfer can bring about research impact by presenting stakeholders with opportunities to discover novel

applications of research outcomes. Studies indicate performance differentials among organizations that transfer knowledge effectively and those that do not (e.g., Cummings & Teng 2003; Hansen 2002; Argote et al 1999). Other studies indicate performance differentials among members with varying network characteristics such as number and strength of network connections (Inkpen & Tsang 2005; Burt 1992).

The network boundaries play an important role in the transfer of knowledge within the R&D network (Carlile, 2002) and consequently, in the creation of research impact. Organizations are typically delineated by boundaries among internal business units. Corporate Research is but one among the many diverse business units within the organization. Researchers need to collaborate with colleagues from other business units in order to gain relevant industry feedback on their research projects and in the same token, other business units need to collaborate with the researchers in order to know the topics that may be of strategic importance to their business units. Unfortunately, in most organizations, there are no formal engagement models that enable these cross-boundary alliances. Most of these collaborations occur in informal networks of like-minded people who seek each other for informal exchange of knowledge, skill, and expertise. Hence, the study of R&D networks should include the broader ecosystem composed not only of the formal project team members but importantly all the other informal members from other business units or even external organizations with whom they collaborate with.

Network range refers to the number of ties that cross network boundaries and is related to the access to new knowledge, that is, knowledge that exists outside the network boundary (Reagans & McEvily 2003; Hansen, 2005). This concept is associated with Burt's (1992, 2004) structural hole, which refers to the gap between unconnected network actors. Burt (1992) describes the myriad of opportunities and benefits for boundary-spanners, i.e., network actors who are able to span or bridge these structural holes.

Small World Networks

Numerous studies found that many social networks exhibit the small-world phenomenon (e.g., Schnettler, 2009; for review see Uzzi et al. 2007), which refers to the smaller-than-expected six degrees of separation between any two randomly selected people (Milgram, 1967; Watts & Strogatz, 1998). Subsequent studies have shown the prevalence of small-world phenomenon in other types of networks as well (e.g., river networks, biological ecosystems, the World Wide Web, etc.). All these networks, therefore, exhibit small-world network characteristics (i.e., short path-length and high clustering) and behavior (Barabasi, 2003; Buchanan, 2002; Newman, 2001). In addition, small-world network structure has been shown to be an efficient structure for diffusion of innovation or new knowledge (Kastele & Steen, 2010; Schilling & Phelps, 2007; Uzzi & Spiro, 2005). One explanation for this is that small-world networks contain well-connected network hubs (i.e., actors that have lots of ties) that bridge otherwise unconnected clusters.

We draw on small-world network theory to determine if the small-world phenomenon occurs in the R&D network under investigation. Studies have found many collaboration networks to be small-world networks (e.g., Oh et al., 2005; Uzzi & Spiro, 2005; Newman, 2001). The benefit of proving that R&D network is indeed a small-world network is that we gain a well-defined and parsimonious description of its network characteristics such as short path lengths and high clustering (i.e., the grouping of network actors). In addition, we also gain a reasonable prediction of its behavior such as: (1) the path lengths will remain short despite additional network members; (2) there exist highly connected actors bridging otherwise unconnected clusters; and (3) the distribution of the network connections most probably will follow the power law distribution.

Synthesis

The above examination of the literature illustrates that studies have established the association between the following constructs: (1) KT and performance; (2) network characteristics and KT; and (3) network characteristics and performance. Most studies linking network characteristics and performance do not identify the mechanism that underlies this association. There is, however, an underlying suggestion that knowledge transfer among interpersonal networks plays a critical role in the resulting performance (Reagans & McEvily, 2003).

Based on this analysis, this research therefore takes the next logical step of linking the three constructs in order to understand the role that KT plays in the relationship between network characteristics and

performance within the context of R&D networks. The conceptual model in Figure 1 expresses their relationships in the following propositions:

P1: Characteristics of the network influence knowledge transfer in the R&D network.

P2: Characteristics of the network influence R&D performance (i.e. Research Impact).

P3: Knowledge transfer in the network influences R&D performance (i.e., Research Impact).

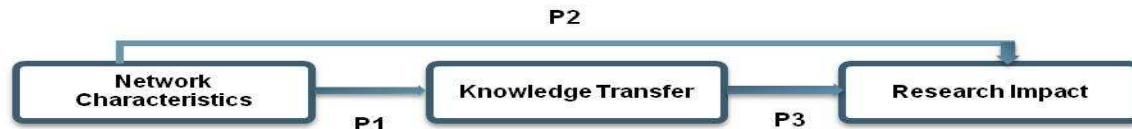


Figure 1 Conceptual Model

Research Methodology

To address the research question and to understand the phenomenon of interest, we conducted an exploratory study of research impact within corporate environment. (Benbasat et al. 1987) recommends case research approach to understand relatively new phenomenon. Interviews with relevant stakeholders were conducted and archival data collected. Simultaneously, an extensive literature search and review was performed in order to find the most appropriate theoretical framework that can provide the lens through which the whole phenomenon of research impact creation can be viewed and analyzed systematically. Once a sufficient understanding of the phenomenon was gained from the analysis of exploratory case study data, the design of the main study and instruments was subsequently done. Findings from this exploratory case study were presented to the Global Head of SCorp Research who gave approval to proceed. In order to facilitate access to SCorp's employees and systems, an internship was arranged for the researcher. This internship status allowed the researcher to be onsite 2-3 days a week during the duration of the study.

We use case study approach in conjunction with social network analysis (SNA). SNA can enhance the insights gained in this case study by providing a visualization of the interaction among project team members within and external to their project team network. Furthermore, SNA facilitates analysis of the different network levels such as the network of individual actors, the network of interacting actors (or dyads), and the network of projects. SNA also enables the examination of how various network characteristics (e.g., centrality, path length, network range, and tie strength) influence knowledge transfer in the network of stakeholders within each of the selected projects. The objective is to determine if there are patterns among the network characteristics of project stakeholders that can influence the knowledge transfer that in turn leads to the creation of research impact. These common patterns can be distinguished visually in the network diagrams and verified through the computed network variables such as centrality, network range, path lengths, and strength of ties. The case study protocol and social network survey details are provided in the Appendix.

The main study consists of two parts. Part 1 looks at all the six publicly funded research projects that SCorp participated in Australia. Out of these six projects, only one is considered to have achieved research impact. Part 2 looks at the 90 publicly funded research projects in Europe. Out of these 90 projects, a criteria-based selection method was used to select four projects deemed to have achieved high research impact for detailed case study and SNA. This paper reports the findings for Part 1.

Exploratory Study

An exploratory study was conducted at the beginning to understand the nature and scope of the perceived problem of low research impact among the research projects and to identify the relevant factors that may affect the research impact. Another aim of the case study is to know more about the organizational environment of SCorp as well as SCorp Research. The following sub-sections present the overview of the research approach taken during the exploratory study and present the findings of the exploratory study.

The steps taken during the exploratory study are as follows: First, preliminary meetings were held with SCorp Research management to define the problem being addressed and its scope. Initial set of questions

were prepared in order to define the relevant terms such as research impact and the existing processes of dissemination and exploitation of research outcomes, in the context of the SCorp Research projects. From the results of these meetings and the subsequent exchange of emails and documents, a clearer view of the problem being addressed has emerged. Furthermore, better insight on SCorp Research, its charter, and its business model is garnered. The preliminary data gathered from these meetings were then compiled and used as the basis for interview preparation. Interviews with relevant staff shown in Table 1 were then conducted. The aim of these semi-structured interviews is to understand how these members view the research impact and the processes involved in facilitating research impact. Concurrently, a comprehensive review of the literature is performed to identify the potential constructs and its measurements. Analysis of the interview data and the documents gathered and the knowledge gained from the literature is then performed. The results of this analysis feed into the design of the ensuing case study and the construction of the preliminary theoretical model.

Table 1 Exploratory Study Interview List

Interviewee	Position
P1	Business Development Manager, SCorp Research
P2	Director, Business Development & Communications, SCorp Research
P3	Assistant to the Director, Research Portfolio Office (RPO), SCorp Research
P4	Director, Project Management Office (PMO), SCorp Research

SCorp Research Overview

The research environment is SCorp Research, the corporate research division of a global software company, SCorp. The core business of SCorp is business software. SCorp's 2011 revenue is around U\$18.7B and it employs more than 66,000 employees worldwide. More than 97,000 companies in more than 120 countries use its software. It spends roughly 13% of annual revenue on R&D. Last year, its R&D spending was \$2.1B. Figure 1 shows SCorp Research with its diverse stakeholders interconnected and embedded in a complex mesh of exchange relationships within the network.

SCorp Research was acquired by SCorp in 1999 from another computer company that was itself being acquired by bigger computer company not interested in its research division. SCorp Research has the charter to provide systematic thought leadership by identifying and shaping emerging IT trends and to contribute to SCorp's product portfolio by generating breakthrough technologies through applied research. In contrast to SCorp's product groups and development labs that work on new functions and releases, the researchers explore opportunities that haven't yet been developed into products.

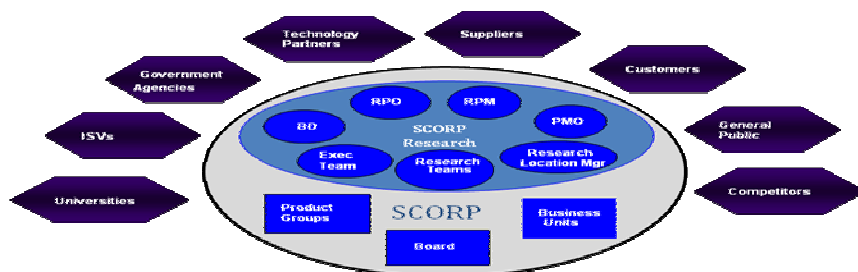


Figure 2 SCorp Research and its Ecosystem

Figure 2 shows the external and the internal stakeholders for SCorp Research. The external stakeholders include universities, ISVs (Independent Software Vendors); Government, Agencies, Technology Partners, Suppliers, Customers, General Public, as well as SCorp's competitors. SCorp Research collaborates with these diverse set of external stakeholders in selected research consortia engaged in some publicly funded projects financed by government funding bodies such as the European Commission, Australian Research Council etc. In addition, SCorp Research's internal stakeholders consist of the SCorp executive board, the

various product and solution groups within the company, as well as the various business units. SCorp Research itself is comprised of different stakeholders such as the executive team, the research teams, research location directors, and other research support teams such as: BD (Business Development); RPO (Research Portfolio Office); RPM (Research Program Managers); PMO (Project Mgmt Office).

SCorp Research as a Global Research Network

In order to access and leverage local knowledge and expertise distributed globally in pockets of excellence, SCorp Research has expanded globally. It has established 15 research centers in major cities all over the world including Palo Alto, Montreal, Karlsruhe, Sophia Antipolis, Ra'anana, Pretoria, Tokyo, and Brisbane. SCorp Research employs more than 500 employees worldwide.

SCorp Research Business Model

SCorp Research's business model is based on co-innovation through joint and collaborative research. In collaboration with leading universities, partners, customers, and SCorp product groups, SCorp Research drives the development of promising ideas and prototypes into market-ready software for maximum customer value. External collaboration is primarily done by participating in publicly funded projects as part of research consortia that include external parties such as universities, partners, and customers. Internal collaboration, on the other hand, is done by engaging in transfer projects with internal SCorp business units and product groups. The primary driver is to leverage what is learned in the engagement with publicly funded projects in the transfer projects done with internal SCorp business units.

In order to ensure ongoing internal collaboration between SCorp Research and SCorp product groups, SCorp executive board through its financial controllers and at the discretion of its innovation council sets aside an innovation budget. This innovation budget can only be accessed by SCorp Research if they engage in transfer projects with SCorp Product and Solution Groups as well as other business units. The terms of engagement (ToEs) of these transfer projects are negotiated yearly and signed by the respective executives of the product and solution groups and SCorp Research.

To create impact within SCorp, SCorp Research explores and defines potential “next big things” for SCorp (maximum-impact next-generation technologies and applications) and enhances the current portfolio with internal transfers of applied research into existing SCorp products. SCorp Research plays a major role as a deal-enabler and door-opener by convincing customers and prospects of SCorp’s innovative force and commitment.

SCorp Research Performance Issues

This study is motivated by a practical concern that SCORP Research is facing with respect to impact generation of its research projects. Research impact, as discussed previously, is achieved when product groups developed research artifacts into commercial software or solutions.

SCorp Research collaborates with numerous stakeholders interconnected and embedded in a complex mesh of exchange relationships within the innovation network such as that shown in Figure 1. Interactions among stakeholders enhance opportunities for possible innovations and subsequent research impact through the exchange of resources, including knowledge. Knowledge transfer can help to bring about research impact by presenting stakeholders with opportunities to discover novel applications of research outcomes.

Analysis of the interviews indicates a perceived problem of difficulty of transferring research outcomes from publicly-funded projects into the internal stakeholders within the company such as the product & solutions group and other business units. For these publicly funded projects, there is a work package that specifies the dissemination and exploitation plans for the project outcomes. Dissemination refers to all the activities that are designed to raise the awareness of stakeholders – current and potential- to the existence and the value proposition of the project. While exploitation refers to all activities that attempt to harvest and utilize research outcomes from the project. Most of the publicly funded projects are conducted by loosely-coupled research consortia typically comprised of more than 5 organizations, which

can be corporations, public organizations, or universities. The contract signed prior to the start of the project specifies that intellectual property (IP) rights associated with each organization. While dissemination activities can be a concerted effort by the consortium, most of the dissemination activities are conducted by individual organizations according to the IP allocations decided by the contract agreed upon prior to the project kick-off.

A look at the project database shows that SCorp Research has been involved in 96 publicly-funded projects in the period from 2003 to 2010. Of these 96 projects, 53 have associated transfer projects. Of these 53 transfer projects, however, very few research outcomes have been productized and commercialized.

Case Study

This section presents the case study done on all of the six publicly funded research projects which SCorp Research conducted together with other universities from 2005 to 2009 in Australia.

Data Collection

Data was collected via semi-structured interviews and social network survey of project members, observations during team meetings and other company events and via access to corporate portal and databases. Out of the total of 48 project members, 42 were interviewed as part of the case study and simultaneously surveyed using a social network survey questionnaire either face-to-face or over the phone. The response rate is 87%. These 42 respondents resulted in 145 nominations for project-related interactions. The interviews ranged from 30 -45 minutes and were transcribed. The transcripts were coded and analyzed following the methodology prescribed in Miles & Huberman (1994). Separate case reports were prepared for projects PR1 to PR6 for within-case analyses. Then all six cases were analyzed simultaneously for the cross-case analyses. For brevity, this paper reports only the cross-case analysis.

Table 2 Research Projects - Data Collection

Project	# of Project Members	Case Study & SNA Respondents
PR1	7	5
PR2	10	9
PR3	6	5
PR4	12	10
PR5	7	7
PR6	6	6
TOTAL	48	42

Case Study Results and Discussion

All 42 respondents were interviewed and surveyed either in person or via phone. The duration for interview and social network survey ranged from 60 to 90 minutes on average. All interviews were recorded and transcribed. Six questions were asked on topics such as research impact definition and measures, facilitators & inhibitors, influence of knowledge transfer (KT) on research impact and general process of research impact. This section provides a summary of the analysis of the interview transcripts.

There is a converging definition of research impact among the various project stakeholders. However, there are different prioritizations of research impact measures. For most of the participants, research impact happens when the research outcome is used by others. The difference in the definition depends on the roles played by each project member and their relevant target customer (see Table 3).

Table 3 Project Member Affiliation, Roles, and Targets

Project member	Academic Partner	Industry Partner	
Roles	University	SCorp Research	Internal SCorp Business Units
	Chief Investigators (Profs)	Project Liaison	Industry business units
	Other academic staff	Location Director	Industry solution management
	PhD Students	Global Head	Product and technology unit
	Post-Docs	Research Support Groups (BD, RPO, PMO, Communication)	
Targets	Academic community General community	Internal SCorp Business Units	Customers in different industries

Furthermore, two types of research impact are delineated: (1) practical impact where the research outcome is used in industry and (2) academic impact, where research outcome is published in academic journals or conferences. Different measures are associated with these two types of impact (see Table 4).

Facilitators and inhibitors of research impact are also dependent on the type of research impact. For practical impact, some of the facilitators mentioned are: selection of research topic that is of relevance to the industry; someone to nurture the network; and full engagement of participants. While for academic impact, the following facilitators are mentioned: selection of relevant topic from an academic perspective (which might not coincide with what is relevant for the industry), assurance of rigor in the research design and the execution of the actual research and finally, careful selection of journals and conferences.

Table 4 Measures of Research Impact

Practical Impact	Academic Impact
research outcome of practical use in industry, organization, or market place	research outcome advancing specific field of study
Impact on product portfolio: Projects being taken up by product groups	Publication in high quality journals/conferences
Patents; Inventions; Prototypes	Research Funding Acquisition
Visibility within the ecosystem: requests for further engagement from industries	Citations & bibliometric indicators
Thought leadership	Invitation to keynotes, journal editorship
Publications	Training/mentoring of high quality PhDs

When asked if knowledge transfer (KT) has an influence on the achievement of research impact, there is a general consensus among the project members interviewed that KT influences research impact. What emerged in the analysis of the interview transcript is that there is a distinction between internal and external KT (see Table 6). And what is interesting is that the different type of KT influences different outcomes (see Table 7). In particular, the within-project KT is important to complete the research process and the research project itself. Whereas, the external project KT is more relevant to achieving practical research impact. Most academic partners naturally regarded their industry liaison from SCorp Research as representing SCorp itself. In reality, SCorp is a big corporation made of diverse business units and product groups with diverse interests. SCorp Research is only one of these units and itself is also a research provider and the potential gateway to industry product groups within the wider SCorp enterprise. The role of the industry liaison (who is coming from SCorp Research) is crucial in facilitating external project KT and therefore, in achieving practical research impact.

Table 5 Facilitators and Inhibitors of Research Impact

	Facilitators	Inhibitors
Practical Impact	<p>Awareness of what is relevant to industry;</p> <p>Someone to nurture the network: to follow-up leads and provide feedback from industry;</p> <p>Full engagement of both industry partners and academic partners</p>	<p>Not being aware of what is relevant to the industry partner;</p> <p>Differences in objectives: industry focus changes quickly in response to market while PhD topics, once decided are not easy to change;</p> <p>Differences in time frames: industry partners expect results in shorter time frames than what PhD research can provide</p> <p>Lack of appreciation by industry partners of people in academia and vice-versa</p>
Academic Impact	<p>Relevance of research topics;</p> <p>Careful selection of target journals and conferences;</p> <p>Internal vetting of submissions to increase quality of submission;</p> <p>Access to relevant data;</p> <p>Rigorous research design and execution</p> <p>Level of interaction with other academics</p>	<p>Poor selection of research topic;</p> <p>Sloppy application of research methods and design</p> <p>Very little time spent in validating research results; good a proposing new systems or models or architecture with no strategy to evaluate its effectiveness & usability in real world</p>

Table 6 Internal and External Knowledge Transfer

Internal KT (i.e., Within-project KT)	External KT (i.e., Outside-project KT)
Among project members	Project members and their external network within the industry partner's business unit
Among chief investigator & industry partner	Project members and their external network outside the industry partner's business unit but within the industry partner's company
Among chief investigators & PhDs	
Among industry partner & PhD	

Finally, there is a distinction between the research process (i.e., the standard process from formulation of the research question to research design, execution, analysis, and write-up) and the research impact process (i.e., the process of achieving impact). In addition, while the research process is clear, the research impact process is not clear and very ad-hoc. Furthermore, while resources are allocated to the research process, there are no resources allocated for the research impact process.

Academic partners believe that completion of the research process with research outcome is adequate while industry partner sees the production of research outcome as a starting point of the research impact process (see Fig 3). The research outcome is an artefact that needs to be transferred to industry product groups to make impact. And for such artefact to be transferred to industry product groups, it must be packaged with the appropriate use cases and scenarios, relevant prototypes, and business cases those appeals to specific industry product group. This is the stage where the role of the industry liaison becomes critical because he must find the right contact person to that specific industry product group, establish contact, and proactively promote that artefact.

**Figure 3 Research Process and Research Impact Process**

Social Network Analysis Results and Discussion

The lists of project members were gathered from a project database. The informants were asked to check the veracity of the project member list and to add persons outside of the list with whom they also collaborated during the course of the project. All the 42 case study interviewees were asked to answer the social network survey that looked at the two dimensions of tie strength i.e., frequency and closeness of relation (Hansen, 2002). They were also asked to rate the ease of KT to each of the nominated project member according to the instrument used by Reagans & McEvily (2003). On average, network data collection took 30 minutes for each participant. All the network data were processed using UCINET ver6.328 and visualized using NetDraw ver2.104. All the network characteristics are based on the definitions and calculations in Wasserman & Faust (1994) and are provided in the Appendix. The following diagrams and tables shows the results of the social network analysis performed on all the six projects (PR1 to PR6) and the global network, which is the agglomeration of all the five projects.

Table 7 Project Network Characteristics

	PR1	PR2	PR3	PR4	PR5	PR6	Global
Network Size	43	54	35	51	59	51	145
Network Density	0.1406	0.0881	0.1815	0.0831	0.059	0.1078	0.0249
No of Ties	254	252	216	212	202	275	519
Research Impact?	0	0	0	0	1	0	

Table 7 presents the different network characteristics such as network size, density, number of ties for each project. It also shows whether research impact has been created from the SCorp Research's perspective. Note that out of the six projects, only project PR5 has achieved impact, i.e., the project's research outcome has been transferred to an internal product group within SCorp.

Network Graphs (Cross-Project Analysis)

Figure 4 shows the network graphs of all the projects, PR1 to PR6.

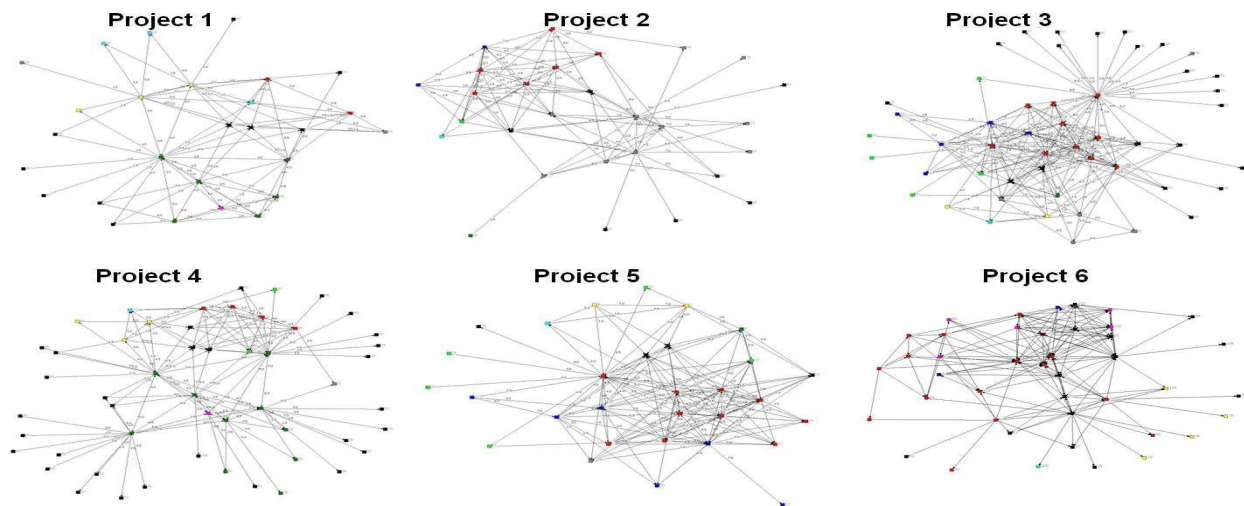


Figure 4 Network Diagrams

Small-world network Characteristics (Cross-Project Analysis)

The network analysis at the project and global level describes the social environment within which KT and

research impact occurs. We test whether SCorp's R&D network exhibit the small-world network phenomenon in order to understand its global behavior. For example, we would know that short path lengths exist between any two actors in the network, which would have implications on the ease of KT. Small-world-network coefficient Q is equal to $[(LLN/LLR)/(CCN/CCR)]$, where LLN is the average path length of the network; LLR is the average path length of same size random network ; CCN is the clustering coefficient of the network; and CCR is the clustering coefficient of same size random network . A small-world network has Q much greater than 1 (Uzzi & Spiro, 2005). Table 8 shows the computation of the small world network coefficient, Q , for all the projects as well as for the global network.

Table 8 Computation of the Small World Network Coefficient Q

Project	Clustering Coefficient			Path Length			SW Q
	Actual (CCN)	Random (CCR)	Ratio	Actual (LLN)	Random (LLR)	Ratio	
PR1	0.388	0.117	3.3162	2.541	2.267	1.1209	2.95864
PR2	0.441	0.094	4.6915	2.095	2.698	0.7765	6.04183
PR3	0.483	0.168	2.8750	1.87	2.118	0.8829	3.25628
PR4	0.452	0.067	6.7463	2.524	2.799	0.9018	7.48130
PR5	0.445	0.086	5.1744	2.539	3.333	0.7618	6.79257
PR6	0.408	0.092	4.4348	2.579	2.503	1.0304	4.30409
Global	0.457	0.007	65.285	3.139	3.764	0.8340	78.2846

Network Characteristics (Cross-Project Analysis)

Figure 5 shows comparison of the different network characteristics across the different projects. Simple observation shows that PR5 has a relatively higher small-world-network coefficient Q , higher network centralization, higher network density, higher distance-based cohesion, and lower average distance than the rest of the other projects. This interesting observation can form the basis of testable hypotheses that can be tested in another study.

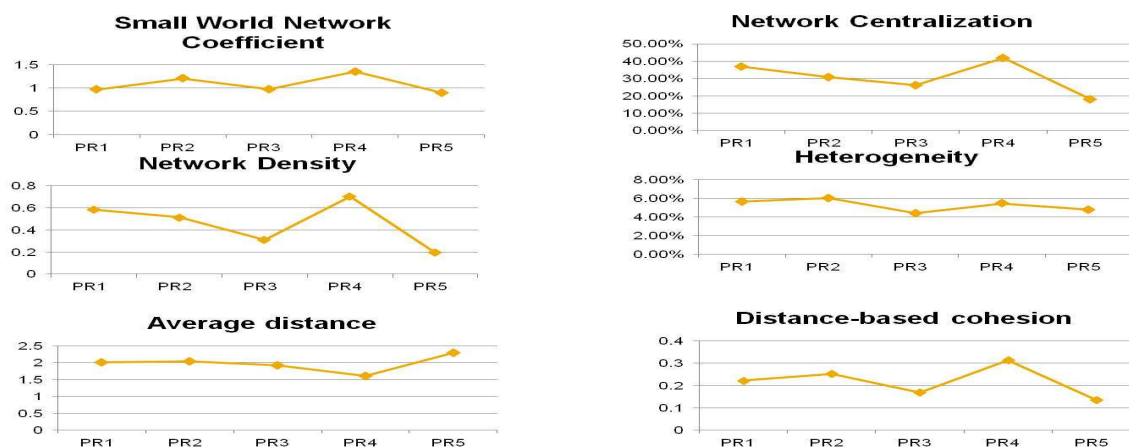


Figure 5 Network Characteristics at Project Level

Network Boundaries

The network actors are color-coded according to which organization they are affiliated with. Furthermore, in Figure 6, boundaries are defined that delineate the following groups: the first circle (i.e., the innermost

circle; colored red in the diagram) denotes the boundary of the project. Hence, all the actors within this first circle are the core members of the project. The second circle (colored yellow) denotes the boundary of SCorp Research in that geographic area. For this case study, all the actors within the second circle are members of SCorp Research in Australia. The actors within the third circle (colored blue) are SCorp Research members located in other geographic locations such as Europe and USA. The actors within the fourth circle (colored green) are employees from other business units within SCorp. Finally, all the actors outside the fourth circle are persons nominated by project members and stakeholders that do not belong to any of the first four circles.

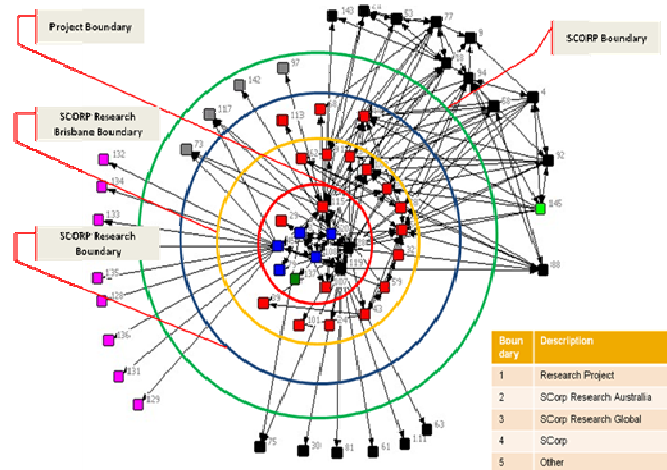


Figure 6 Defining the Network Boundaries

By arranging the actors according to which circle they belong produced very interesting patterns among the six projects. Note that for research impact to be achieved there has to be communication from the core project members (i.e., actors within the first circle) to somebody in the fourth circle, as members of the fourth circle are SCorp employees working in other business units within SCorp and are the potential transfer partners and consumers for SCorp Research's project outcomes.

Network Boundaries (Cross-Project)

Fig 7 shows the six projects with their actors rearranged to correspond to the circles and boundaries defined above. For most of the projects, there are a lot of ties crossing the project boundary (red circle or first circle) to the local SCorp Research boundary (yellow circle or second circle). There are a lot of ties crossing the project boundary to the SCorp boundary (green circle or fourth circle). This is not a surprised as most of the project members are in universities that are different entities than SCorp. However, there are very few projects with ties that cross the boundary between SCorp Research Global and the SCorp internal business units (blue circle or the third circle). PR5 has four ties crossing this boundary. PR4 has two ties while all the other projects have none. From the point of view of creating practical impact, this is a critical zone because the ties crossing this boundary represents connections to the internal business units or product groups within SCorp and these are the potential internal stakeholders who are the potential transfer partners who can take the research artifact into a product.

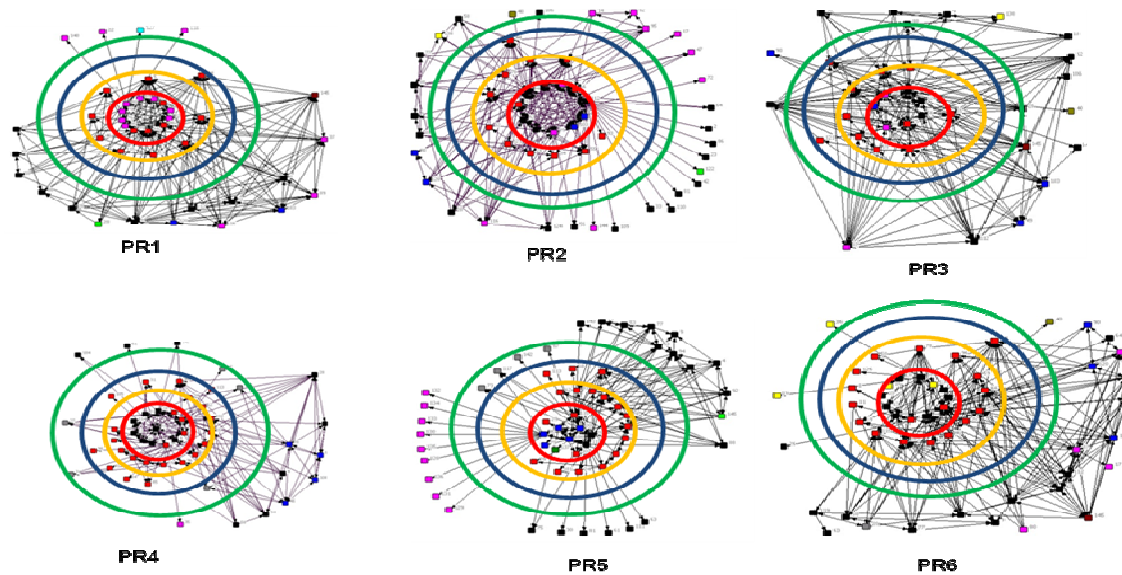


Figure 7 Network Boundaries defined for the six projects

Conclusion

The exploratory case study combined with social network analysis provided valuable insights into the nature and scope of the phenomenon of research impact creation in the corporate context of SCorp Research. The results of the exploratory study allowed the researcher to be familiar with the organizational environment of SCorp as well as SCorp Research, in particular, SCorp Research's charter, its business model, and its organizational processes in and across its ecosystem.

The findings of the exploratory study and the subsequent case study on six research projects provided more detailed insights into the definition and measures of research impact within projects conducted with both academic and industry stakeholders. The results shows that while there is a converging definition of research impact (i.e., use of research outcome), there are different opinions as to how research impact is measured and how it can be achieved. In particular, the measures, facilitators, and inhibitors are dependent on the type of research impact – (1) practical research impact, in which research outcome is used in industry or (2) academic research impact, in which research outcome is published in academic journals or conferences. In research consortia where members are coming from both industry and academia, it is important to note this potentially conflicting definitions and measures of research impact as it has important implications in how the research project is conducted. There is a resounding consensus that knowledge transfer (KT) influences research impact. Analysis shows the distinction between two types of KT: internal KT (i.e., within-project KT) and external KT (KT outside the project). Whereas internal KT is essential in the execution of the research project, it is the external KT that is more relevant to achieving practical research impact. The reason is external KT spans the project boundary into that of the internal SCorp business units that could potentially take the research artifacts into a product. Another interesting outcome is the distinction between the research process and the research impact process. And while the research process is clear and quite standard, the research impact process is not clear and very ad-hoc. Finally, resources are typically allocated to the research process but not the research impact process. These preliminary findings already suggest some areas on which improvement can be made. However, further reliability and validity can be achieved by conducting similar research on a different cohort of research projects to provide theoretical replication and saturation.

The associated social network analysis of all the six projects as well as the global project networks also yielded some interesting results. Out of the six projects examined, project PR5 is the only project that has achieved research impact (based on the SCorp definition). Preliminary analysis of PR5's network characteristics shows that it has a relatively higher small-world network coefficient in comparison with the other projects (the only other project that has a higher SWQ is PR4). PR5 also has a higher average

distance. Furthermore, PR5 has the lowest network density, network centralization, and distance-based cohesion (see Figure 5). These interesting observations can form the basis of testable hypotheses that can be tested in another study.

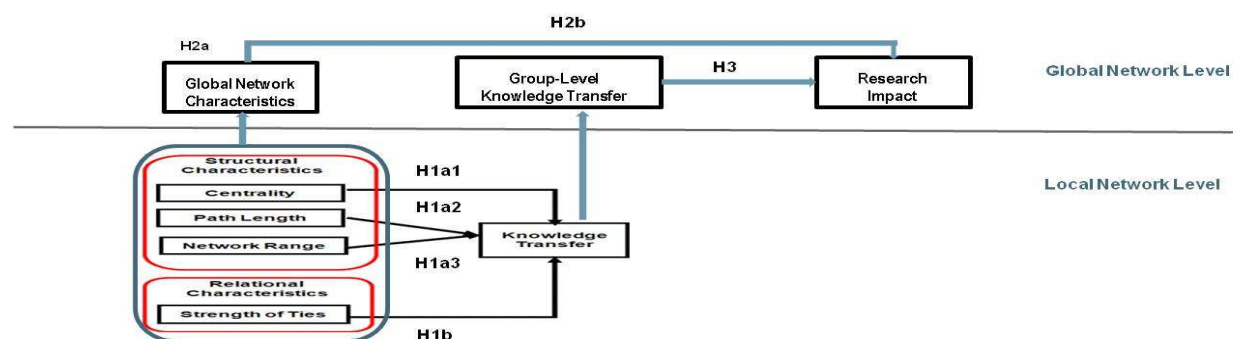
The rearrangement of the social network graphs of all the six projects according to the boundaries relative to the project also shows some interesting results (see Figure 7). For research impact to be achieved there has to be communication from the core project members (i.e., actors within the first circle) to somebody in the fourth circle who is SCorp employees in other business units - the potential transfer partners and consumers for SCorp Research's project outcomes. Again, out of the six research projects, only two projects PR4 and PR5 have this type of communication links. This empirical evidence relates the concepts of structural holes (Burt, 1992, 2005) and boundary-spanning (Levina & Vaast, 2005). An interesting possibility is the provision of visual network evidence of the boundary-spanning process across structural holes.

Further Research

The results of the case study and the associated social network analysis provided some insights into how project teams in research projects conducted in a corporate context achieves research impact. As mentioned above in the Discussion section, while the results have been enlightening, further research can be performed on a different cohort of research projects to see if similar findings are replicated. Part 2 of the study where the cases were selected based on replication logic of successful project may provide further support to the findings.

Another step is to conduct statistical regression analysis to establish the relationship between the network characteristics and knowledge transfer and research impact. This will be a challenge due to the interrelated nature of network data. However, advances in the field of network analysis have yielded the process called Multiple Regression Quadratic Advanced Placement (MRQAP) which is able to deal with this limitation. Further studies could also look at exponential random graph models (ERGMs) to determine how the global structure emerges from local processes.

The recommended studies provide interesting challenges as the relationships between the different variables have to be done in different levels of analysis. For example, knowledge transfer is essentially a dyadic process. Some of the network variables that are of interest such as the strength of ties, centrality, and distance are essentially across dyads. Hence it is possible to correlate these network variables with knowledge transfer at the dyadic level of analysis. However, research impact is at the project level. In order to test the relationship between network characteristics and research impact, we have to be careful to select network characteristics at the project level, such as centralization and so on. We envision such investigation would require multi-level analyses. The proposed research model is shown below



Acknowledgements

I wish to thank the associate editors and three anonymous reviewers who have provided constructive feedback on the original draft of this paper. Thanks to my PhD supervisors – Prof Iris Vessey and Prof Peter Green, for their unwavering support in this journey. Thanks to Nina Vayssiere (nee Kissel) who have initiated this collaboration. I thank all the informants who have participated in this research.

References

- Allen, J., A. D. James, et al. (2007). "Formal versus informal knowledge networks in R&D: a case study using social network analysis." *R&D Management* 37(3): 2007.
- Aral, S., B. E., et al. (2006). "Information, technology, and information worker productivity: task level evidence." *Proceedings of the 27th annual International Conference on Information Systems*, Milwaukee.
- Argote, L. (1999). *Organizational Learning: creating, retaining, and transferring knowledge*, Boston, Kluwer Academic.
- Balachandra, R. and J. H. Friar (1997). "Factors for Success in R&D Projects and New Product Innovation: A Contextual Framework." *IEEE Transactions on Engineering Management* 44(3): 276-287.
- Barabasi, A.-L. And Bonabeau, E. 2003. Scale-Free Networks, *Scientific American* (5), 60-69.
- Benbasat, I., D. K. Goldstein, et al. (1987). "The Case Research Strategy in the Studies of Information Systems." *MIS Quarterly* 11(3): 369-386.
- Borgatti, S. P. and R. Cross (2003). "A Relational View of Information Seeking and Learning in Social Networks." *Management Science* 49(4): 432-445.
- Borgatti, S. and P. C. Foster (2003). "The Network Paradigm in Organizational Research: A Review and Typology." *Journal of Management* 29(6): 991-1013.
- Buchanan, M. (2002). *Nexus: Small worlds and the groundbreaking science of networks*, New York, W.W. Norton & Co.
- Burt, R. S. (1992). *Structural Holes: The Social Structure of Competition*, Cambridge, MA, Harvard University Press.
- Burt, R. S. (2005). *Brokerage and Closure: An Introduction to Social Capital*, Oxford, Oxford University Press.
- Carlile, P. R. (2002), "A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development", *Organization Science* (13:4), July-August 2002, pp 442-455
- Cross, R., A. Parker, et al., Eds. (2003). *Networks in the Knowledge Economy*. New York, Oxford University Press
- Cummings, J. L. and Teng, B.S. 2003. "Transferring R&D knowledge: the key factors affecting knowledge transfer success," *Journal of Engineering & Technology Management* (20: 1/2), pp.39 -69
- Davenport, T. (2005). "Thinking for a living: How to get better performance and results from knowledge workers", Harvard Business Press
- Granovetter, M. (1973). "The Strength of Weak Ties," *American Journal of Sociology* (78:6) pp.1360-1380.
- Hansen, M. T. (2002). "Knowledge networks: Explaining effective knowledge sharing in multiunit companies," *Organization Science*, (13:3), pp. 232-248.
- Hansen, M. T., Mors, M. L. and Lovas, B. (2005). "Knowledge Sharing in Organizations: Multiple Networks, Multiple Phases," *Academy of Management Journal*, (48: 5), pp. 776-793
- Hitt, M., P. W. Beamish, et al. (2007). "Building Theoretical and Empirical Bridges across Levels: Multilevel Research in Management." *The Academy of Management Journal* 50: 1385-1399.
- Inkpen, A. C. and Tsang, E.W.K. 2005. "Social Capital, Networks, and Knowledge Transfer," *Academy of Management Review*, (30:1), pp. 146-165.
- Kastele, T. and Steen, J. (2010). "Are small world networks always best for innovation?" *Innovation: Management, Policy & Practice*, (12: 1), pp.76-88.
- Kilduff, M. and Tsai, W. (2003). *Social Networks and Organizations*, London, SAGE Publications, Ltd.
- Krackhardt, D. and J. R. Hanson (1993). "Informal Networks: the company behind the charts." *Harvard Business Review* 71(4): 104-111.
- Krantz, M. (2012), "Microsoft, Intel, Google outspend Apple on R&D", *USA Today*, accessed 04 May 2012 <http://www.usatoday.com/money/perfi/columnist/krantz/story/2012-03-20/apple-marketing--research-and-development-spending/53673126/1>
- Levina, N. and Vaast, E. (2005). "The Emergence of Boundary Spanning Competence in Practice: Implications for Implementation and Use of Information Systems", *MIS Quarterly*, Vol 29, Issue 2
- McKinsey (2011). "R&D strategies in emerging economies: McKinsey Global Survey results." *McKinsey Quarterly*.
- Miles, M. and Huberman, M.A. (1984). "Qualitative Data Analysis" 2nd Edition, Sage Publications, London

- Nahapiet, J. and S. Ghoshal (1998). "Social capital, intellectual capital, and the organizational advantage." *Academy of Management Review* 23(2): 242-266.
- Newman, M. E. J. 2001. "Scientific Collaboration Networks I: Network Construction and Fundamental Results," *Physical Review E* (64).
- Noteboom, B. (1999). "Innovation and the Inter-firm Linkages: new implications for policy," *Research Policy*, (28), pp. 793-805.
- Oh, W., Choi, J. N. and Chung, M. (2006). "Coauthorship Dynamics and Knowledge Capital: The Patterns of Cross-Disciplinary Collaboration in Information Systems Research," *Journal of Management Information Systems*, (22: 3), pp. 265-292.
- Ojanen, V. and O. Vuola (2006). "Coping with the multiple dimensions of R&D performance analysis." *International Journal of Technology Management* 33(2/3): 279-290.
- Reagans, R. and McEvily, (2003). "Network Structure and Knowledge Transfer: The Effects of Cohesion and Range," *Administrative Science Quarterly*, (48:2), pp. 240-267.
- Schilling, M. and Phelps, C. (2007). "Interfirm Collaboration Networks: The Impact of Large-scale Network Structure on Firm Innovation," *Management Science*, (53:7), pp. 1113-1126.
- Schnettler, S. (2009). "A Structured Overview of 50 years of Small-World Research.," *Social Networks*, (31), pp. 165-178.
- Tsai, W. P. (2001) . "Knowledge transfer in intraorganizational networks: Effects of network position and absorptive capacity on business unit innovation and performance," *Academy of Management Journal*, (44:5), pp. 996-1004.
- Uzzi, B. (1997). "Social structure and competition in interfirm networks: The paradox of embeddedness," *Administrative Science Quarterly*, (42:1), pp. 35-67.
- Uzzi, B. and Spiro, J. (2005). "Collaboration and Creativity: The Small World Problem," *American Journal of Sociology*, (111:2), pp. 447-504.
- Uzzi, B. Amaral, L., Reed-Tsochas, F. (2007). "Small-world networks and management science research: a review", *European Management Review*, vol 4, pp 77-91
- von Krogh, G., K. Ichijo, et al. (1998). *Bringing Care into Knowledge Creation of Business Organizations*.
- Wasserman, S. and Faust, K. (1994). *Social Network Analysis*, Cambridge, Cambridge University Press.
- Watts, D. J. and Strogatz, S. H. (1998). "Collective dynamics of small-world networks," *Nature* (393), pp. 440-442.

Appendix A: Case Study Protocol

- **Problem Description**
 - *Derive the definition and measures of research impact*
 - *Derive the factors (facilitators & barriers) to research impact*
 - *Investigate the relationship between research impact and knowledge transfer*
 - *Investigate the relationship between research impact and network characteristics*
- **Selection of Cases**
 - Publicly Funded Projects done or ongoing within the last 3 years (coded)
 - PR1, PR2, PR3, PR4, PR5, PR6
- **Data Sources**
 - Archival records:
 - Research Project proposals
 - Meeting minutes
 - Papers published
 - Patent applications
 - Transfer documents
 - Informants (interview)
 - Principal Investigators
 - SCORP Liaison researcher
 - PhD students
- **Case Study Questions**
 - Level 1 Questions: Questions asked of the interviewees
 - In your opinion, what is research impact?
 - What are the measures or manifestation of research impact?
 - What factors facilitate research impact?
 - What factors hinders research impact?
 - To what extent does knowledge transfer affect your project's research impact?
 - Describe the process the project had to go through to achieve impact.
 - Level 2 Questions: questions asked of the individual project
 - Has the project created impact?
 - What project impact was created?
 - How was this impact created?
- **Case Study Report Format**
 - Project Title
 - Short Description of the Project
 - Project Duration
 - Project Budget
 - Project Members
 - Associated Research Impact
 - Analysis of Responses to Case Study Questions
 - Project Network Characteristics (SNA Results)

Appendix B: Social Network Survey and Variable Definitions

Tie Strength (adapted from Hansen 1999, 2002)
1. How frequently do (did) you interact with this person (on average over the past two years)? 1 once a day 2 twice a week 3 once a week 4 twice a month 5 once a month 6 once every second month
How close is (was) the working relationship between you and this person? 1 very close 2 3 4 somewhat close 5 6 7 distant

Knowledge Transfer (adapted from Reagans & McEvily 2003) Answers are in Likert Scale of 1 to 7; 1= strongly disagree and 7 = strongly agree
1. It would be easy for me to explain to this person a key idea concept, or theory in my area of expertise.
2. This person's expertise makes it easy for me to explain a key idea, concept or theory in my area of expertise.
3. Anyone in my area of expertise can explain easily to this person a key idea, concept, or theory in our area
4. I can explain easily to anyone in this person's area of expertise a key idea, concept, or theory in my area.
5. It would be easy for me to explain to this person new development in my area of expertise.

Variable	Definition	Paper(s)	Measures
Research Impact	The degree of influence that a research outcome has on current and future product portfolio	SCorp's definition of impact	The number of Terms of Engagement (ToE) contract generated. ToE represents the funding support provided by client stakeholders
Knowledge transfer	Knowledge is transferred when learning takes place and when the recipient understands the intricacies and implications associated with that knowledge so that he/she can apply it.	Argote& Ingram, 2000 ; Ko et al. 2005; Reagans & McEvily 2003	5-7-item instrument using a 7-point Likert scale adapted from Reagans & McEvily (2003)
Centrality	A key measure in social network analysis; indicates how an actor is linked to others in the network. Different categories of centrality- degree, closeness, betweenness, and eigenvector-based measure	Ahuja et al 2000 Freeman 1979; Bonacich 1972	Wasserman & Faust, 1994
Range	The number of ties that cross institutional, organizational, or social boundaries	Burt 1992: p148	Wasserman & Faust, 1994
Path length	The global measure of separation among the actors	Watts & Strogatz 1998	Wasserman & Faust, 199
Clustering Coefficient	the degree to which an actor's partners are also partners with each other	Uzzi & Spiro 2005	Wasserman & Faust, 1994
Strength of Tie	The strength of the relational tie between actors and is a function of (1) a baseline level of attraction; (2) a positive identification effect; and a negative competition adjustment	Hansen, 2002	2-item instrument using a 7-point Likert scale adapted from Hansen (2002, 2005)